



Radiation exposure management

ALARA

As Low As Reasonably Achievable

Regulatory requirements

28-35-211d. Radiation protection programs

- Develop, document, and implement a radiation protection program sufficient to ensure compliance with the provisions of these regulations.
- Use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and public doses that are as low as is reasonably achievable (ALARA).



Regulatory requirements

28-35-211d. Radiation protection programs

- Constrain air emissions of radioactive material to the environment, excluding radon-222 and its daughters, so that the individual member of the public likely to receive the highest dose is not expected to receive a total effective dose equivalent in excess of 10 mrem (0.1 mSv) per year from these emissions.
- Review the radiation protection program content and implementation at intervals not to exceed 12 months



Considerations

- State of technology
- Economics
- Environmental impact
- Public interest



Management responsibilities

- Supervise program and define employee responsibilities
- Employee awareness of program and management's commitment to it
- Perform periodic audits
- Employee training
- Give Radiation Safety Officer sufficient enforcement authority and resources
- Modify procedures/incorporate engineering or process controls if exposures reduced at a reasonable cost



RSO and the Radiation Protection Staff

Vigilance

- Know the origins of radiation exposures in the facility.
- Look for ways to reduce exposures.
- Ensure adequate equipment and supplies available to workers.



External exposure limits

- 5 rem deep dose to the whole body (DDE): tissue depth 1 cm
- 50 rem shallow dose to skin or extremities (SDE): tissue depth 0.007 cm
- 15 rem to the lens of the eye (LDE): tissue depth 0.3 cm
- 1 rem = 0.01 Sv = 1 cSv



Individual monitoring requirements

- Adults >0.5 rem DDE, >5 rem SDE, >1.5 rem LDE
- Minors >0.1 rem DDE, >0.5 rem SDE, >0.15 rem LDE
- Declared pregnant woman >0.1 rem DDE
- Individuals entering a high or very high radiation area (>0.1 rem in one hour @ 30 cm; >500 rad in one hour @ 1 m)
- $1 \text{ rad} = 0.01 \text{ Gy} = 1 \text{ cGy}$



Investigational Levels for External exposure

Based on cumulative exposure over the year

- Level I 10% annual limit for occupational exposure:
 - 500 mrem/y DDE, 5000 mrem/y SDE, 1500 mrem/y LDE
 - Average monthly exposure: 42 mrem DDE
- Level II 30 % annual limit for occupational exposure:
 - 1500 mrem/y DDE, 15000 mrem/y SDE, 4500 mrem/y LDE
 - Average monthly exposure: 125 mrem DDE



Investigation process

>Level 1, < Level II

- Timely investigation by RSO or designee
- Determine root cause, work habits and exposures of others engaged in similar tasks
- Determine if additional safety measures or training needed to reduce exposures
- Determine if an engineering or process controls were bypassed



Investigation process

> Level II

- All actions as specified for > Level 1.
- Considerations to reduce probability of occurrence.
- Report of the actions reviewed by licensee management at its first meeting following completion of the investigation.
- RSO/designee will re-establish a unique set of Investigational levels for the affected individual.

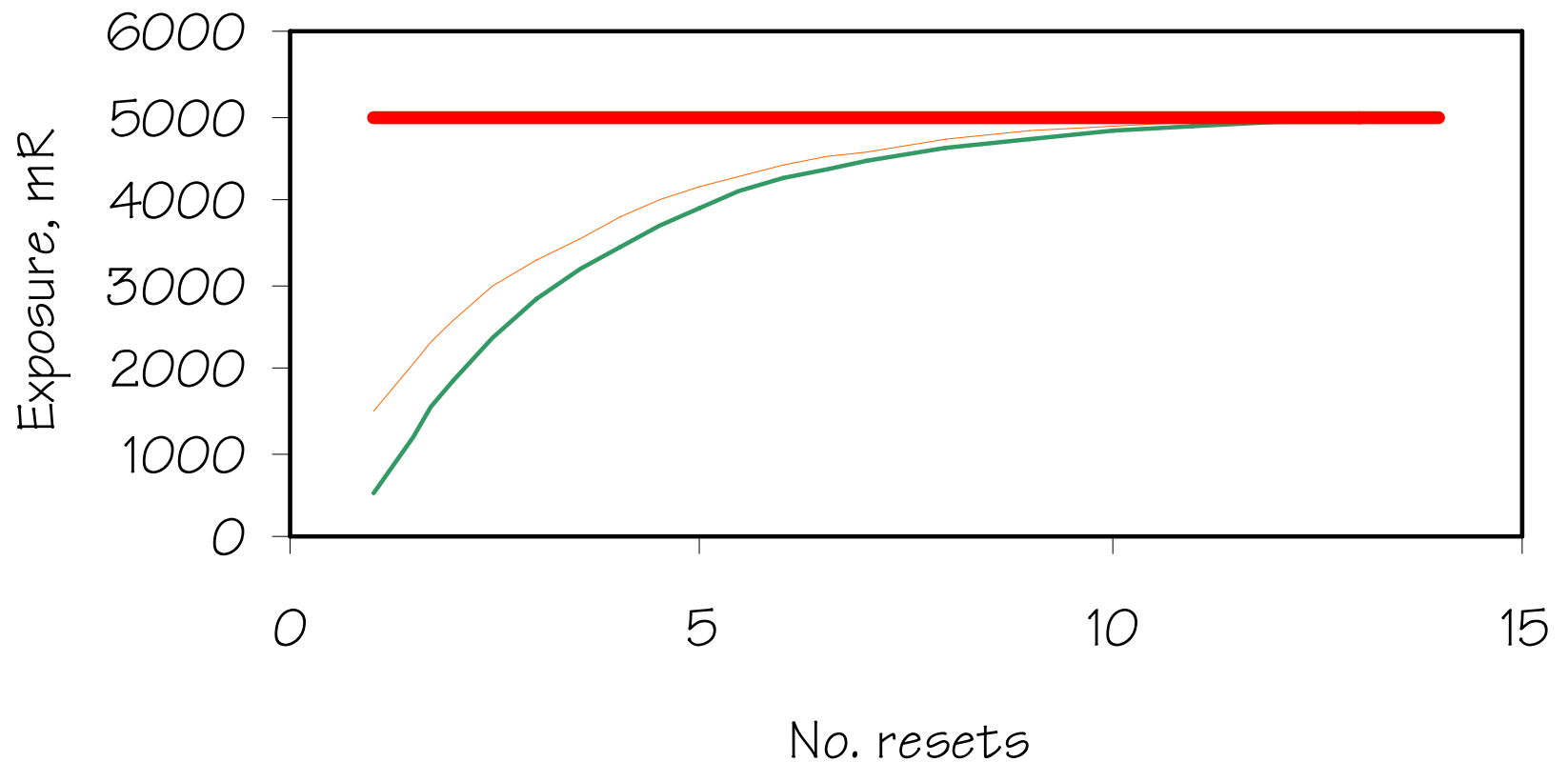


Example of re-establishment of new Investigational limits

- 10 %/30 % of remaining exposure if just exceeded Level II for DDE (3500 mrem): Level 1 = $350 + 1500 = 1850$, Level II = $1050 + 1500 = 2550$ mrem
- 10%/30% of remaining exposure if again just exceeded new level II for DDE (2550 mrem): Level 1 = $245 + 2550 = 2795$, Level II = $735 + 2550 = 3285$ mrem



Investigational Levels



— Level I — Level II — DDE annual limit

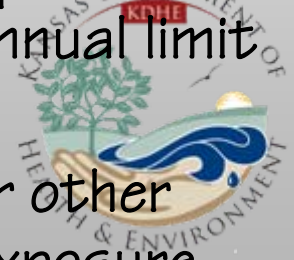
Flags that indicate an over-exposure may occur before the end of the year (DDE)

- 417 mrem/month
- 1250 mrem/quarter
- 3750 mrem on or before the end of the third quarter
- 4583 mrem on or before the beginning of the last month of the year
- Someone that has been doing 40h/wk fluoroscopy for the past 12 months with 6 months worth of “M” listed on dosimeter report.

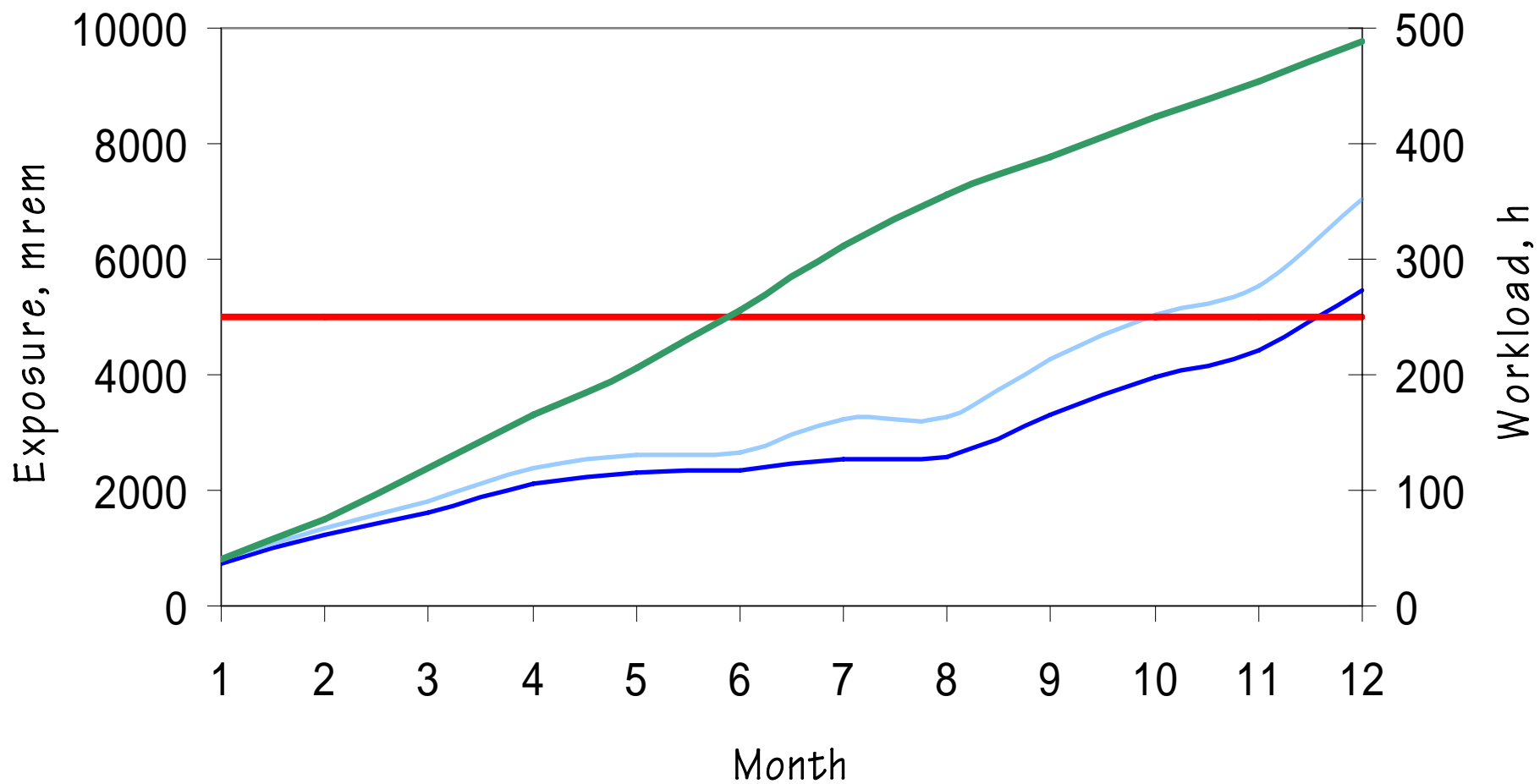


Flag that indicates an overexposure may have already occurred

- Getting your monthly report for November in mid January of the next year indicating an 11 month cumulative exposure of 4583 mrem!
 - Be proactive.
 - Your dosimetry contract should have provisions for at least 48 h processing
 - RSO/designee should be knowledgeable of all personnel on a dose projection tract that indicates an annual limit will be exceeded before the end of the year
 - Institute increased monitoring frequencies or other administrative controls to prevent an overexposure from occurring.



Cumulative Exposure



— DDE — SDE — DDE annual limit — Workload

Administrative controls to limit exposure

- Restrict access to source
- X-ray:
 - Evaluate devices (optimize technique factors and frame rates, insure shielding installed and functioning as designed)
 - Use whole body weighting factors such as Webster equations



Webster equations

- $H_e = H_{\text{collar}} \times 0.3$
- $H_e = 1.5 \times H_{\text{waist}} + 0.04 \times H_{\text{collar}}$
- X-ray only, typically only used for fluoroscopists, usually only collar badge used
- Specifically named individuals
- Requires 2nd dosimeter if exposed to radiation from non-machine based emission sources
- Extremity monitoring required
- Weighting factors do not apply to skin/extremity exposure (SDE)
- Not a substitute for ALARA!
- Requires annual review



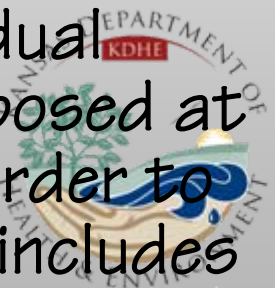
Internal exposure

- Required if personnel will receive > 10% ALI (inhalation or ingestion)
- 2000 h at DAC will give an internal exposure of 5 rem CEDE and 50 rem to any individual organ or tissue
- Bioassay program may be required
- Air monitoring program may be required
- Annual whole body limits based on internal and external exposure: Whole body TEDE = DDE+CEDE



Final notes

- ALARA program becomes far more complicated if workers have both external and internal exposures. Typically internal dose has to be manually added to cumulative exposure as dosimetry vendors will track only external exposures. A database such as NRC's REMIT may have to be used to track internal and external exposures.
- Tracking of all radiation exposures an individual receives is required, even if the person is exposed at another licensee or registrant's facility, in order to ensure annual limits are not exceeded. This includes both external and internal exposures.



NRC FORM 5
(9-2004)
10 CFR PART 20

U.S. NUCLEAR REGULATORY COMMISSION

APPROVED BY OMB NO.3150-0006

EXPIRES: 09/30/2007

OCCUPATIONAL DOSE RECORD FOR A MONITORING PERIOD

Estimated burden per response to comply with this mandatory collection request 20 minutes. This information is used to ensure that doses to individual do not exceed regulatory limits. This information is required to record/annually report individual occupational exposure to radiation to ensure that the exposure does not exceed regulatory limits. Send comments regarding burden estimate to the Records and FOIA/Privacy Services Branch (T-5 FSO), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by Internet e-mail to: infocollect@nrc.gov, and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202, (3150-0006), Office of Management and Budget, Washington, DC 20503. If a means used to impose an information collection does not display a currently valid OMB control number, the NRC may not conduct or sponsor, and a person is not required to respond to, the information collection.

1. NAME (LAST, FIRST, MIDDLE INITIAL)		2. IDENTIFICATION NUMBER		3. ID TYPE	4. SEX <input type="checkbox"/> MALE <input type="checkbox"/> FEMALE	5. DATE OF BIRTH (MM/DD/YYYY)
6. MONITORING PERIOD (MM/DD/YYYY - MM/DD/YYYY)	7. LICENSEE NAME			8. LICENSE NUMBER(S)	9A. <input type="checkbox"/> RECORD <input type="checkbox"/> ESTIMATE	9B. <input type="checkbox"/> ROUTINE <input type="checkbox"/> PSE

INTAKES				DOSES (in rem)	
10A. RADIONUCLIDE	10B. CLASS	10C. MODE	10D. INTAKE IN μ CI		
				DEEP DOSE EQUIVALENT (DDE)	11.
				LENS (EYE) DOSE EQUIVALENT (LDE)	12.
				SHALLOW DOSE EQUIVALENT, WHOLE BODY (SDE,WB)	13.
				SHALLOW DOSE EQUIVALENT, MAX EXTREMITY (SDE,ME)	14.
				COMMITTED EFFECTIVE DOSE EQUIVALENT (CEDE)	15.
				COMMITTED DOSE EQUIVALENT, MAXIMALLY EXPOSED ORGAN (CDE)	16.
				TOTAL EFFECTIVE DOSE EQUIVALENT (ADD BLOCKS 11 AND 15) (TEDE)	17.
				TOTAL ORGAN DOSE EQUIVALENT MAX ORGAN (ADD BLOCKS 11 AND 16) (TODE)	18.
				19. COMMENTS	

20. SIGNATURE - LICENSEE	21. DATE PREPARED
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Use procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and public doses that are ALARA

